# METAL FOAM BY SPACE HOLDER TECHNIQUE

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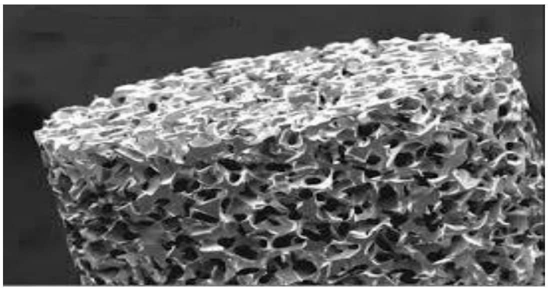
## ABSTRACT

*In recent years Metal foams are of great interest due to their unique properties, which is combination of various properties such as high stiffness combined with low density and high strength to weight ratio etc. Especially aluminium foam is more popular due to their high resistance to corrosion and light weight. In this study, we focus on the mechanical properties (Plateau Strength) of aluminium foam by varying different parameters such as porosity percentage, cold compaction pressure, sintering time and temperature. In present study metallurgy route for the production of aluminium foams via space holder technique is studied. Various space holder materials have been used for production of Al foam such as urea, wax, ammonium bicarbonate, salt, etc. the effect of adding various space holders on the mechanical properties of the foam have reviewed in this paper.*

***Keywords*: *aluminium foam, plateau strength, powder metallurgy, sintering, space holder.***

## I. INTRODUCTION

A metal foam is an important category of materials which having unique properties such as sound absorbing capacity, fluid permeability, low thermal conductivity, high energy absorption capacity due to these unique properties metal foam use in various field such as aerospace , automobile, biomedical implants , chemical industries, traffic dividers, sensors in electronics fields etc[1].The metal which is commonly used to manufacturing of metal foams is aluminium because its having properties like high corrosion resistance, light weight etc. However some other metals are uses in order to production of metal foams, such as nickel, copper, titanium and tantalum etc. Metal foam is a cellular structure which is made by a cellular metal containing a large volume fraction gas filled pores. These pores can either be completely sealed (Closed-cell foam) or can be open interconnected network (Open-cell foam) [2]. The history of Metal Foam or Porous Metal is a new type of material and dates back to the 1940s [9].Between 1050s to 1970s a number of experiment were performed and in second effort some old techniques were re-establishment in order to generate new idea in the field of metal foam.



**"Fig".1 Metal Foam [3]**

## II. APPLICATIONS OF METAL FOAM

2.1 Crash absorber in vehicles

Metal Foam plays an important role as a crash absorber. Metal foams are attached in front of vehicles in order to protect passenger and expensive components of vehicles. Many vehicle companies want to make a crash absorber such that it can works with minimum fuel consumption by weight reduction of crash absorber. Hence, Metal foam plays important role it can also reduce sound emission.

2.2 Metal Foam in heat exchanger

Many investigation show that Metal Foam works as good compact type heat exchanger, due to its large surface area and low specific weight. In many chemical plants metal foams plays an important role due to its high heat transfer efficiency. It uses in cryogenic application for heating purpose [4].

2.3 Biomedical implants

Metal foam of open-cell type also use in orthopaedic implants. Due to good biocompatibility and higher corrosion resistance steel foam are most popular in biomedical implants. Scaffold type steel foam is used. Young modulus of metal foam can be controlled by tailoring its porosity [5].

2.4 Aerospace industries

Aluminium foams are primary needs in aerospace industries due to its low specific weight and high corrosion resistance. Generally Metal Foam used in the form of sandwich panel. Currently most of the researches are focused on sandwich panel. Wings of aeroplane are made by Al foam due to its high velocity impact and due its isotropic mechanical properties [6].

2.5 Electronic device

Metal foams are also useful in electronic industry to control overheating of electronic components, because more compact electronic device produce more heat. Hence Metal foam increases the life of electronic components. In electronic industry thermal management of electronic component like semiconductor can increase its performance.

## III. METAL FOAM PRODUCTION METHOD

There are mainly two type of metal foam production method, casting method and powder metallurgy. In casting method initially metals are in liquid state. In this method control of Pore size and its uniform distribution is difficult. Also it is useful method for metal having low melting points. In present we are using Powder Metallurgy route. In this method metals are use in solid state. Powder metallurgy method consists of several steps like mixing of powder, compaction, primary sintering, actual sintering and other secondary operation.

3.1 Space holder technique

This technique also follow powder metallurgy route. In this technique two type of powder are required metal powder and space holder material. Space holder material may be metallic or non metallic. Various type of space holder are use in this technique like NaCl, Carbamides, Wax, mg and other organic compounds. This method is best for high melting point materials. Pore size and its uniform distribution can be easily controlled. [7].

Various steps in space holder technique are given as follows:

3.1.1 Mixing of metal powder

In this step metal powder and space holder are mixed. Also some other additives are mixed with powders for bonding and reduction of friction etc. Intermixing of different grain size in same composition called blending. This can be achieved by using some mechanical mixer like ball mills.

3.1.2 Compacting

In this steps mixed powder are compressed using die of desired shape. By applying high pressure small welded joint occurs between metal particles so that compact mixture will be posses a desired shape. Generally applied pressure is in the range of 100-1600MPa. Strength of compacted product in this step is called green strength [8].

3.1.3 Primary Sintering

In this step green compact are heated by furnace. Space holder material will be vaporized and only metal will remain. Metal particles will be joined together like diffusion bonding. Main purpose of this step is removal of space holder. In some cases solvent are also used for dissolution of space holder.

3.1.4 Actual Sintering

Actual sintering are use in order to increase the strength of primary sintered foam. In this step primary sintered are again heated at high temperature. After this sintering Density of semi finished foam also increase due to high bonding strength. Sintering temperature are generally taken as 0.7-0.9 times of melting points of metal [9].

## IV. LITERATURE REVIEW

R. Surace et al. studiedthe effect of various parameters on mechanical properties of Aluminium foam. Space holder technique was used for production of Aluminium foam and NaCl was taken as space holder material. Hot water was used for the dissolution of Nacl space holder. The authors focused on various process parameters like weight %of aluminium powder, compaction pressure and sintering time. Aluminium powder was mixed with Nacl space holder in 30, 40 and 50% by weight. Compaction pressure level was 550, 600 and 650MPa and three sintering time values were 2, 3 and 4 hours. It was found that optimum value of pressure, sintering time and Aluminium fraction for low density and high compressive strength was respectively 550MPa, 2h and 40 weight%. The authors observed that plateau strength increases with the increase in relative density[10].

N. Michailidiset al. processed Al metal foam by space holder technique. The authors used carbohydrate as a space holder material. In this study range of porosity was kept as 50-75 volume %. Compaction pressure was used in the range of 200-350MPa and range of sintering temperature was 600-750$^{o}$C.It was observed that cell walls had more strength with the increasing sintering temperatures. The effect of sintering temperature on mechanical properties was more predominant compared to the reduction in particle size of al powder. Metal foam achieved more strength in the case of liquid phase sintering as compare to the solid state sintering. [11].

Mostafa Alizadeh et al. studied the compression and absorption behaviour of Al composite foam using $Al_2O_3$ compounds in the range of 0-10 volume%. Carbamide (as space holder materials) of mean particle size 1.2mm was used for production of Al composite foam in the porosity range of 50-70 volume%. Specimens were heated at a temperature of 1$40^{\circ}C$for one hour then again heated at temperature of 280 for 4 hours. It was observed that for a fixed porosity of 70% flatness of plateau region increases with the increase in $Al_2O_3$ volume %. He also found that for a fixed 70% porosity compressive strength strictly increases with increase in$Al_2O_3$volume fraction. The author observed that energy absorption capacity of composite foam for all porosity% was higher than Al foam. [12].

Amir Hassani et al. studiedthe production of graded aluminium foams using space holder technique. Granulated ceramic powder of size range 1-5mmwas taken as space holder material. In this experiment compression property of cell graded foam and multi- size cell foam were compared. Cell graded foam means gradient of cell size in a direction perpendicular to the cross section area of metal foam while multi-size cell foam means aggregation of small pores around the large pore. The authors found that multi-size cell graded foam had 6.8% more absorption efficiency as compared to the cell graded foam in a stress- strain analysis for strain range 0-50%. Multi-size cell foam also existed with flatter plateau region as compared to the cell graded foam [13].

Hasan Bafti et al. processed Aluminium foam by powder metallurgy route via space holder technique. Spherical carbamide was used as space holder material in the porosity range 40-85%. Green compact was compressed at a range of pressure 200-400MPa.Sintering temperature range was kept 610-640℃. Sintering time varied from 1-2h.The results show that the energy absorption and compressive strength increases by 18-20% when sintering time changes from 1-2h for a fixed temperature 610℃ . This value increases by70% when sintering temperature changes from 610-640℃ for 2h sintering time. It means effect of sintering temperature was more predominant as compared to sintering time. Optimum pressure in the experiment was 300-330MPa.It was observed that liquid state sintering provides more strength compare to solid state sintering [14].

Magda Laginskaet et al .study was concerned with porous graded material (PGMs) foams based on intermetallic of Fe and Al. Space holder technique was used for production of intermetallic foam where NaCl was taken as space holder material. Two different foams of discrete gradient and quasi continuous gradient foams were produced by proper selection of space holder particle size for different layer of metal foam. Space holder particle size for both metal foams was used in the range of 0.5 to 5mm.Open cell type porous graded material was fabricated in the porosity range of 40-60%.The authors compared compression behaviour of both intermetallic foam and it was found that for quasi continuous graded foam, plateau region was steeper as compared to the discrete graded foam in a compression test for strain range 0-30%. He found that size and shape of space holder plays an important role for precise control of porosity [15].

Cheng Guoa et al. studied on Al foam using bonding agent $MgAl_2O_4$ spinel whisker via space holder technique where NaCl was used as space holder. Al foam was fabricated by sintering and dissolution process. Bonding agent $MgA_2O_4$ can produce strong bond among particles of metal powder. In this experiment green compact was compressed at pressure 400MPa and range of sintering temperature was 650-750℃. The mean pore size and average wall thickness was 450 µm and20 µm respectively. The authors found that aluminium foam produces maximum impact absorption energy175 $MJ/m^3$ with the use of Mg content. It was observed that when 10% Mg was added with Al then its plateau strength was 18.7MPa which is 2.4times as compared to pure aluminium foam case [16].

B. Velasco et al. studied MAX phase metal foam of $Ti_2AlC$ powder using sugar as space holder material. Sintering and dissolution process were performed where water was used as a solvent. Uniaxial Cold Compaction of green body was performed. Space holder particle size was 250-100µmwhile in volume percentage space holder was considered 20, 40, 60 and 80%. Metal foam with porosity 23-76% was successfully fabricated by space holder technique. The authors found that for porosity lower than 40%, expected porosity was high and opposite in case of more than 40% porosity. It was observed that for whole range of porosity the output pore size was smaller than the given space holder size due to shrinkage in sintering and due to splitting of bigger size pore into small pores[17].

## V. CONCLUSION

1. Compressive strength of Metal Foams was more affected by sintering temperature as comparison of sintering time.
2. Composite Metal Foam produced more strength (plateau strength).
3. Smooth and spherical shape space holder provided more uniform pore distribution.
4. During liquid state sintering above certain temperature, compressive strength improved by reduced number of pores.
5. Mechanical properties of regular foam were more than irregular foam because in irregular foam during compression test un-uniform deformation took place.
6. With the help of ANOVA method and DOE we can find out most significant factor.
7. Sometimes powder metallurgy methods are costly due to high cost of fine powders.

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